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Modeling of the Transport Phenomena in Metal Transfer and Weld Formation of GMAW under the Shielding of Ar-He Mixtures

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Abstract

A better understanding of the transport mechanism in the metal during a welding process is important for the improvements in the quality and productivity of welding. This project studied the influences of shielding gas compositions on the transport phenomena in the metal domain during gas metal arc welding (GMAW), which include the transient processes of electrode melting; the droplet formation, detachment, transfer and impingement onto the workpiece; and the weld pool dynamics and bead formation. The present study shows that electromagnetic force, which is affected by shielding gas compositions, plays the most significant role in determining the behaviors of metal transfer. For the same welding power input, the increase of He content in the mixture leads to the formation of larger droplets and the decrease of droplet detachment frequency. The predicted phenomena on metal transfer are consistent with the reported experimental observations.

Electromagnetic Force

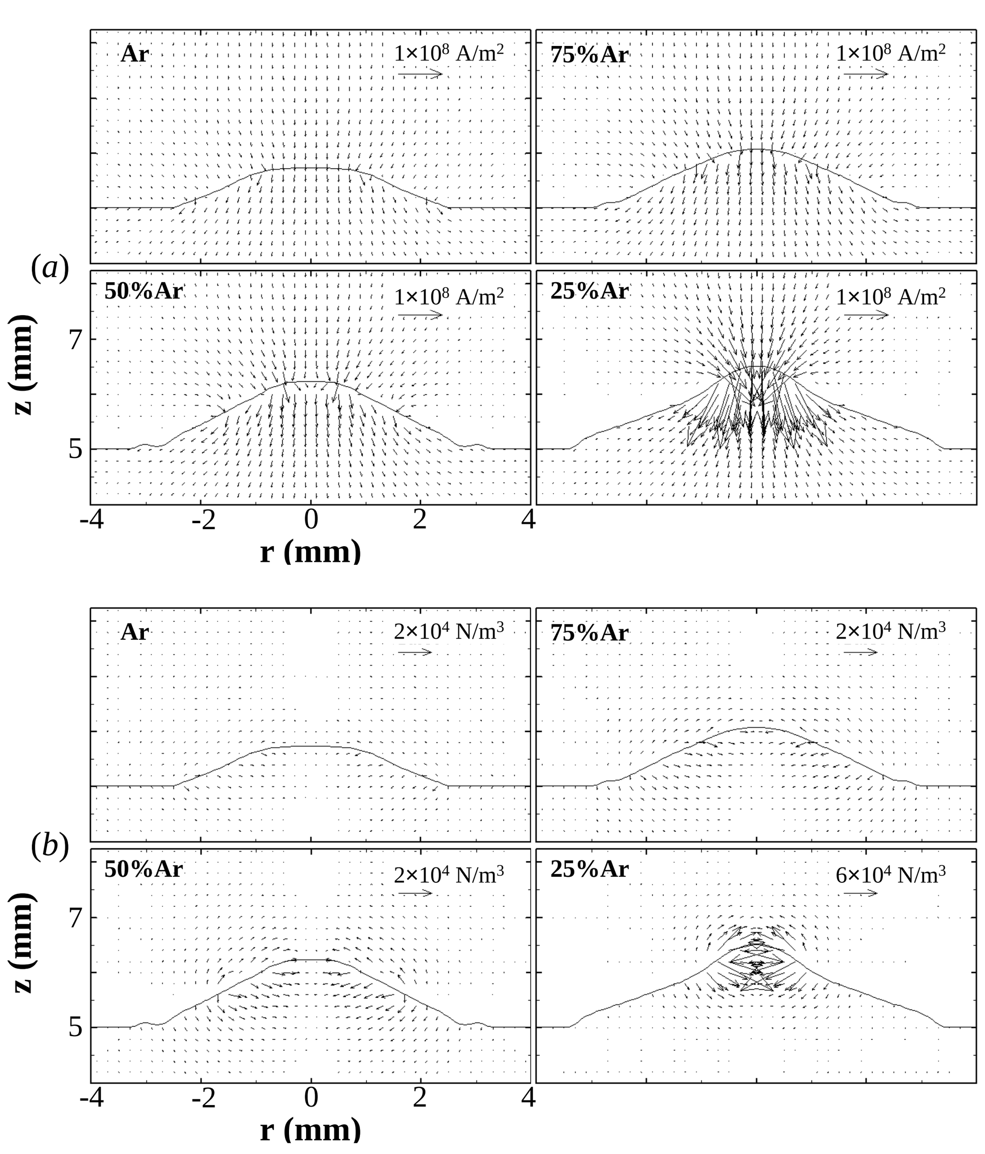

Fig. 3. Distributions of current density (top) and electromagnetic force (bottom) near the weld pool surface.

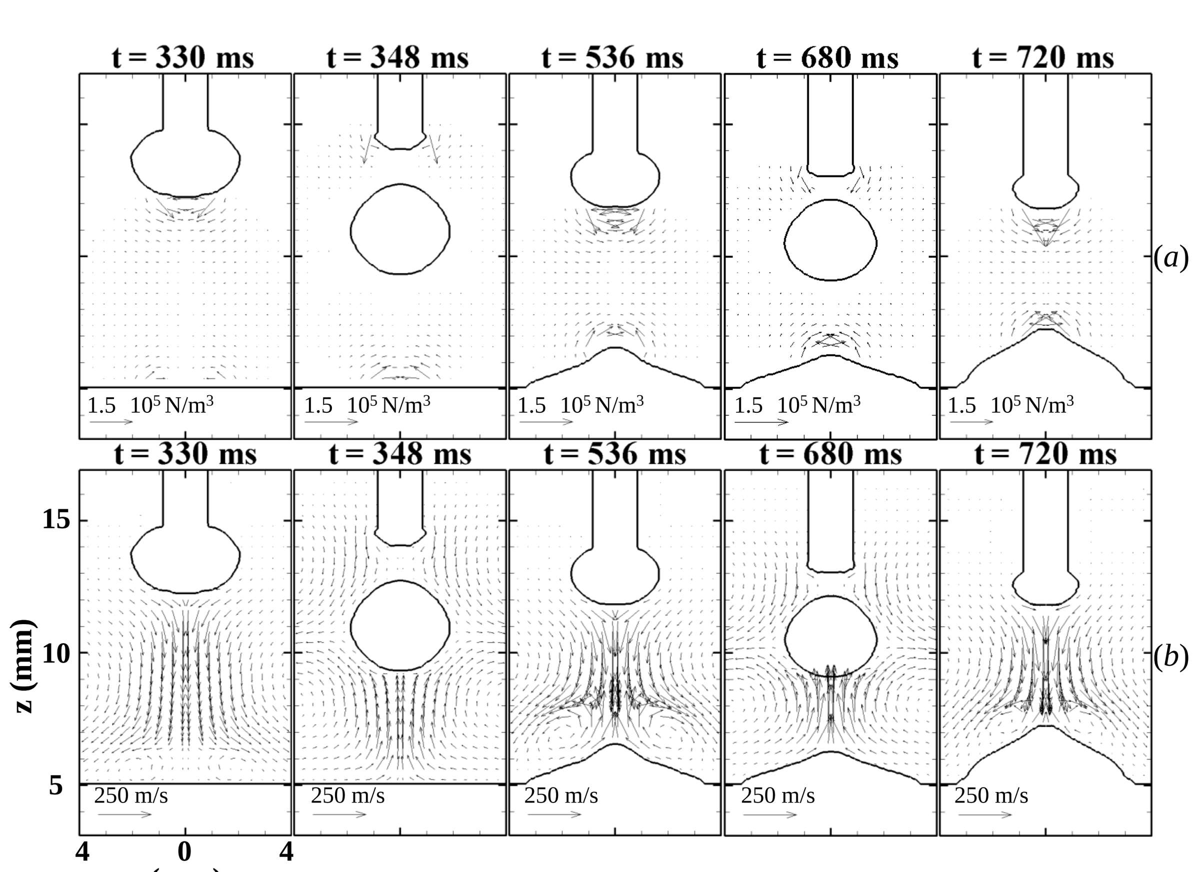

Fig. 4. Distributions of electromagnetic force (a) and velocity (b) in the arc of 25% Ar.

Metal Transfer and Weld Pool Dynamic

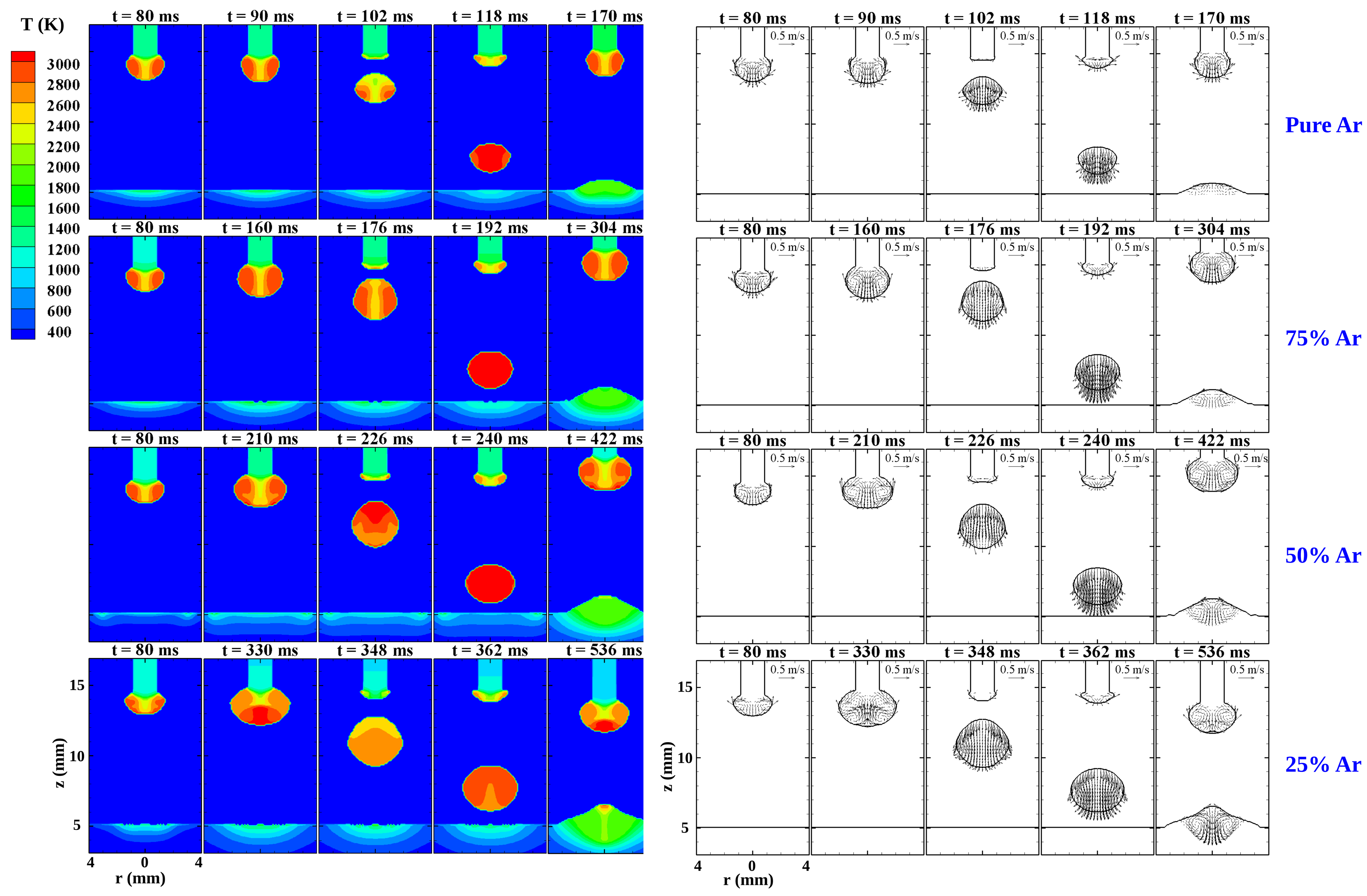

Fig. 1 Distribution of temperature and velocity in the metal, showing a typical droplet formation, detachment, impingement, and weld pool dynamic.

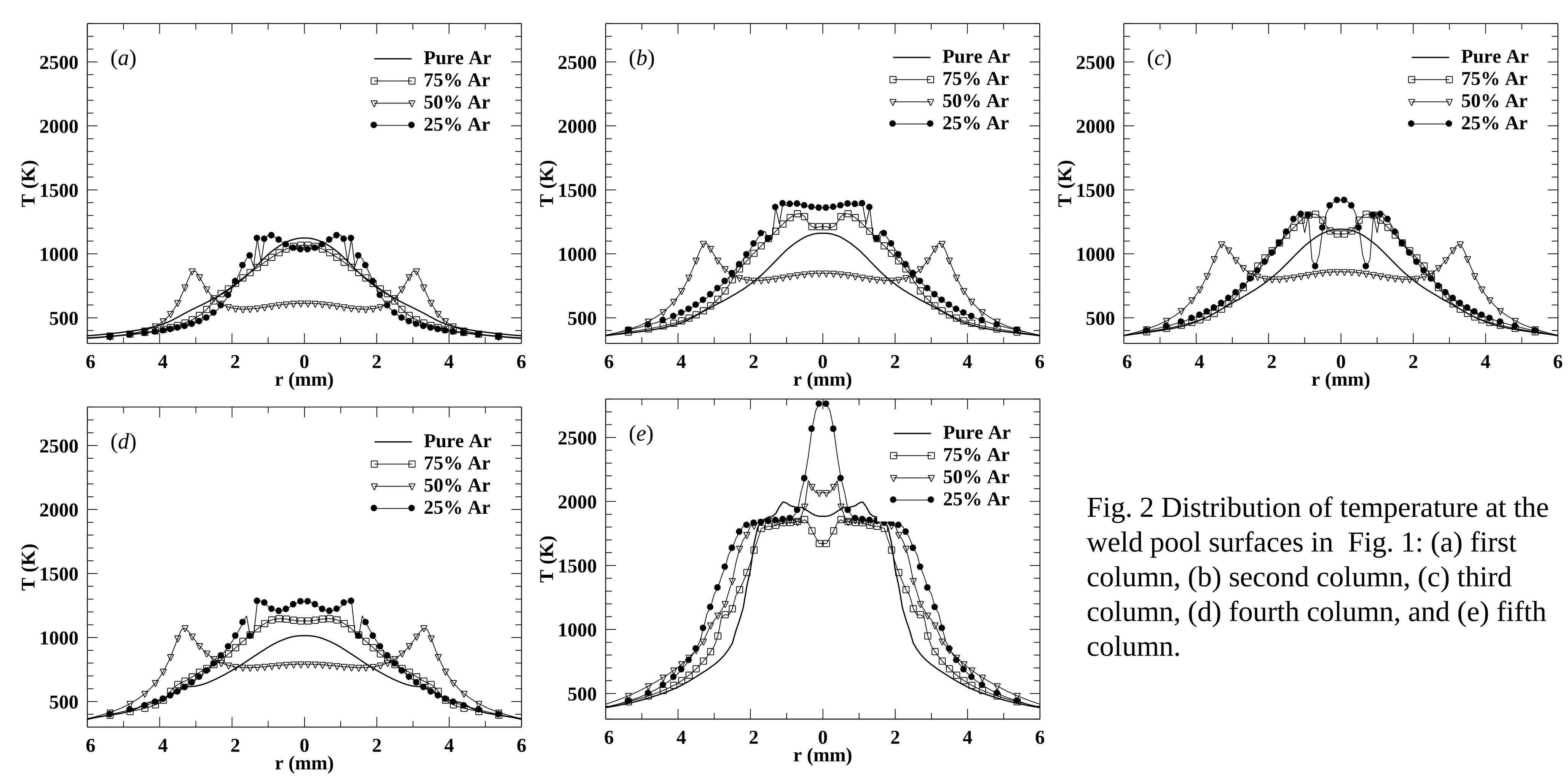

Fig. 2 Distribution of temperature at the weld pool surfaces in Fig. 1: (a) first column, (b) second column, (c) third column, (d) fourth column, and (e) fifth column.

Final Weld Bead Shape

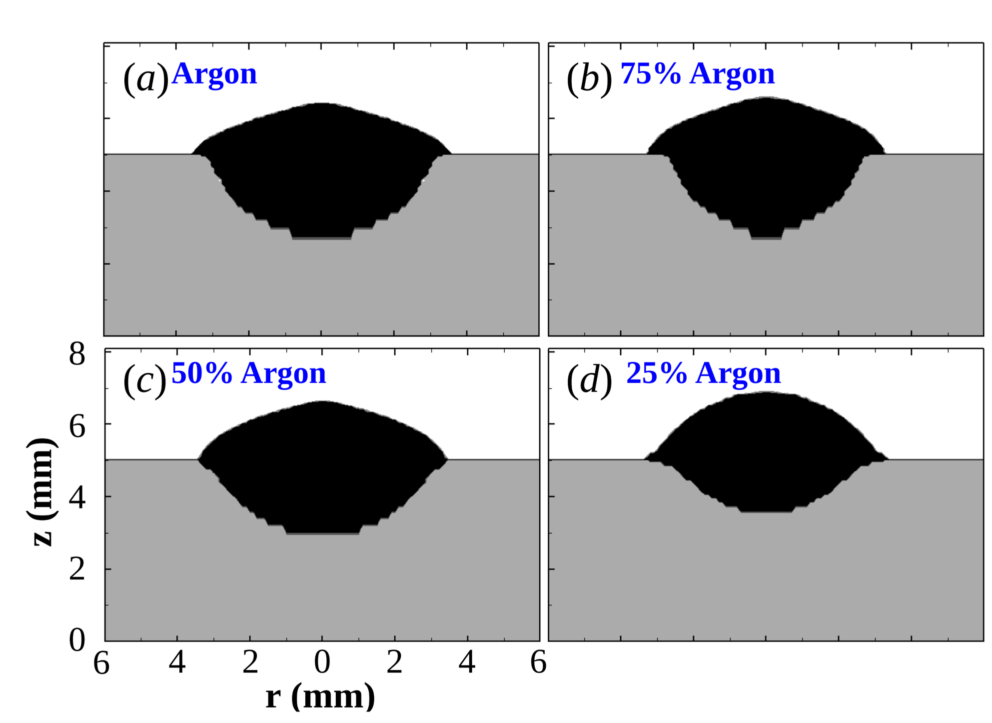

Fig. 5. Comparison of final weld bead shape obtained with different shielding gases.

Conclusion

A comprehensive model have been developed to study the effects of shielding gas compositions on the transient transport phenomena in the metal, including electrode, droplet and workpiece. In pure Ar shielding, the axial component of the electromagnetic force acting on the droplet is a detaching force that contributes to the separation of the droplet from the electrode. In high helium arcs, the axial electromagnetic force at the bottom of the droplet becomes an attaching force, due to arc contraction, which sustains the droplet at the electrode tip and causes the droplet to be less spherical. Hence, the increase of helium content in the shielding gas increases droplet size and droplet formation time, and decreases droplet detachment frequency for welding at a constant welding energy input. A significant upward electromagnetic force near the workpiece is also predicted in high helium arcs, caused by arc contraction. The final weld bead has a shallower penetration depth and broader bead width when helium content increases as a result of fewer droplet impingement with a bigger droplet size and lower droplet velocity.